Vol. 27 No.1 (Januari 2026) 053-060
e-ISSN 2548-6101 p-ISSN 1411-318X

Jurnal Teknologi Lingkungan

Journal Homepage: ejournal.brin.go.id/JTL

Determination of Water Quality Status using the Seawater Pollution Index Method in Eastern Sabang City

Penentuan Status Mutu Perairan dengan Metode Indeks Pencemaran Air Laut di Timur Kota Sabang

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INFORMASI ARTIKEL

Histori artikel:
Diterima 28 Juni 2023
Disetujui 31 Juli 2025
Diterbitkan 31 Januari 2026

Kata kunci:
Kualitas Air
Metode Indeks Pencemaran Air Laut
Tercemar
Wisata Bahari
Timur Kota Sabang

ABSTRAK

Pemantauan kualitas perairan merupakan hal yang penting untuk dilakukan, khususnya di perairan pesisir yang umumnya rentan terhadap pencamaran perairan. Wilayah Kota Sabang merupakan kawasan yang potensial dikembangkan untuk sektor pariwisata. Dengan tingginya rumah tangga perikanan dan adanya aktivitas antropogenik dikhawatirkan dapat menurunkan kualitas perairan di wilayah timur Kota Sabang. Tujuan penelitian ini adalah untuk mengevaluasi kondisi perairan laut terhadap aktivitas wisata bahari di Pantai Timur Kota Sabang dengan menggunakan metode indeks pencemaran dari tahun 2020 sampai 2022 di Mata Ie Resort dan Sumur Tiga. Metode penganalisisan dilakukan dengan indeks pencemaran menggunakan data sekunder dari DLHK Kota Sabang dengan data musim kemarau dari tahun 2020 sampai 2022. Hasil analisis pengukuran parameter fisika, kimia, dan biologi didapatkan bahwa karakteristik ketercemaran air pada tahun 2020 di Sumur Tiga tercemar sedang (5,1) dan di Mata Ie Resort tercemar sedang (5,3); pada tahun 2021 di Sumur Tiga tercemar ringan (4,9) dan di Mata Ie Resort tercemar ringan (4,3); dan 2022 di Sumur Tiga tercemar sedang (5,1) dan di Mata Ie Resort tercemar ringan (4,8). Perairan yang memiliki nilai di atas ambang batas baku mutu yang telah ditetapkan tidak hanya membahayakan kehidupan biota dan lingkungan laut, tetapi juga dapat membahayakan kesehatan manusia, serta dapat merugikan secara sosial ekonomi. Secara keseluruhan pemantauan kualitas perairan perlu dilakukan secara terus menerus di Perairan Timur Kota Sabang agar kondisi lingkungan perairannya tetap terjaga sehingga tidak berdampak buruk pada wisatawan yang berkunjung dan melakukan aktivitas wisata bahari.

ARTICLE INFO

Article history:
Received 28 June 2023
Accepted 31 July 2025
Published 31 January 2026

Keywords:
Water Quality
Sweater Pollution Index Method
Polluted
Marine Tourism
Eastern Sabang City

ABSTRACT

Water quality monitoring is essential, especially in coastal waters, which are generally vulnerable to water pollution. Sabang City is a potential area for development in the fisheries sector. With the high number of fishing households and anthropogenic activities, it is feared that they can reduce water quality in the eastern region of Sabang City. The purpose of this study was to evaluate the condition of marine waters for marine tourism activities on the east coast of Sabang City using the pollution index method from 2020 to 2022 at Mata Ie Resort and Sumur Tiga. The analysis method uses the Pollution Index, secondary data from DLHK Sabang City, and dry season data from 2020 to 2022. The results of the analysis of measurements of physical, chemical and biological parameters showed that the characteristics of water pollution in 2020 in Sumur Tiga were moderately polluted (5.1) and in Mata Ie Resort were moderately polluted (5.3); in 2021 in Sumur Tiga were lightly polluted (4.9) and in Mata Ie Resort were lightly polluted (4.3); and 2022 in Sumur Tiga were moderately polluted (5.1) and in Mata Ie Resort were lightly polluted (4.8). Waters that have values above the predetermined quality standard threshold not only endanger the life of biota and the marine environment, but can also endanger human health and be detrimental socio-economically. Overall, the water quality of the eastern waters of Sabang City needs to be monitored to maintain the environmental conditions for sustainable marine tourism activities

1. INTRODUCTION

1.1 Background

Regarding the East Coast Administration, Weh Island has nine villages in the Sukajaya sub-district. One of them is the Ie Meulee and Anoi Itam villages on the east side of Weh Island. Sabang City in Aceh Province is an area with great potential for development in fisheries (KKP, 2017). Based on the distribution of fisheries fleets and the distribution of fishing equipment, Ie Meulee Village (193) and Mata Ie Resort Village (75) are the sub-districts with the highest number of fishery households (RTPs), with a total of 268 RTPs (KKP, 2017). With the high RTP, the fishermen's activities are also high. Therefore, the high level of these activities and the existence of development also determine the water quality condition (Armita, 2011).

Field observations show that various anthropogenic activities, such as fisheries catch loading and unloading activities, high RTP, tourism activities, and infrastructure development, can cause a decrease in water quality, especially turbidity and total suspended solids (Amri *et al.*, 2013). The increase in tourists visiting the East Coast of Weh Island impacts the increase in garbage on the beach, which causes a decrease in water quality. In addition to the waste problem, the coast of Weh Island has been subjected to abrasion due to the number of trees that have fallen and been cut down by the community (DKPP, 2010).

The problems on the coast are inseparable from the lack of public awareness of the importance of natural resource conservation. Some of the problems related to environmental damage in coastal areas are the large number of mangrove forest logging, waste disposal, fishing that is not environmentally friendly, using anchors in inappropriate locations, and activities that result in reef damage (DKPP, 2010). Previously, from 2010 to 2016, the construction of breakwater infrastructure or breakwaters was carried out. The results showed that the development did not significantly impact the water quality at the location. Then, the water quality condition was again monitored at four location points in Ie Meulee in semester 1 of 2020, and results showed that all parameters still met the quality standards of the Ministry of Environment No. 51 of 2004. This shows that infrastructure activities have not significantly influenced Ie Meulee (DKP, 2020). The research that discusses water quality in terms of mandatory parameters using the Water Index method has not been updated in the waters east of Sabang City. The pollution index (PI) method determines the pollution level by the permissible water quality status according to its designation (Rahayu et al., 2021).

1.2 Research Objective

This study aims to determine the condition of marine tourism in the waters east of Sabang City due to anthropogenic activities in Mata Ie Resort and Sumur Tiga.

2. METHOD

2.1 Data

The data used in this study were from the Sabang City Environment and Forestry Service (DLHK), which consists of physical parameters such as temperature, brightness, turbidity, total suspended solids (TSS), color, odor, oil coating, and waste. As well as chemical parameters such as acidity degree (pH), salinity, COD, BOD, DO, total ammonia, nitrate, phosphate, sulfide, nitrite, cyanide, free chlorine, total phosphat, mercury, chloride, cadmium, chromium hexavaken, lead, copper, fatty oil, zinc surfactant (detergent), and biological parameters, namely fecal coliform. The sample data starts from 2020 to 2022 with two different station points. Water quality data is analyzed to determine the pollution index value.

2.2 Research Procedure

Data collection was carried out in the eastern area of Sabang City. Station one was at Sumur Tiga Ie Meulee Beach (05° 53' 32.7" N, 095° 20' 23.4" E), and station two was at Mata Ie Resort Anoi Itam Beach (05°51' 53.7" N, 095° 21' 16.3"E), which are suspected of having much anthropogenic activity. The location of the research is presented in Figure 1.

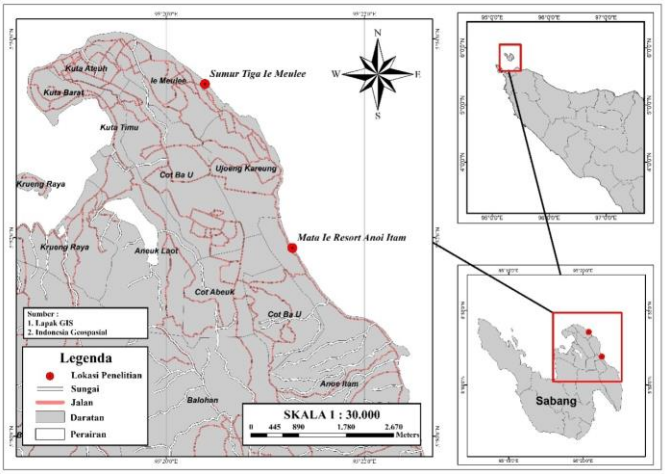

Figure 1. Research location

The measurement of test parameters uses pollution indices from physical and chemical parameters at two station points from 2020 to 2022, concerning Government Regulation No. 22 of 2021 concerning the implementation of environmental protection and management, Appendix VII for marine tourism. In the test parameters, if the concentration is low, it will result in pollution, such as dissolved oxygen (DO), which uses different provisions from the test parameters that have a range in quality standards, such as temperature, brightness, salinity, degree, and acidity (pH). Moreover, the pollution level was evaluated according to KMLH 2003 using the pollution index (IP) method.

Data analysis using the IP method plays a role in determining the magnitude of the pollution level (Nemerow & Sumitomo, 1970). To assess the level of water quality pollution according to KMLH No.115/2003, as seen in Appendix II, it is calculated with the following formula (Equation 1):

$$IP_j = \sqrt{\frac{(C_i/L_{ij})M^2 + (C_i/L_{ij})R^2}{2}} \quad \ldots\ldots(1)$$

Where:
IP: Pollution Index (j)
Ci: Concentration of water quality parameters (i)
Li: The concentration of water quality parameters (i) listed in the Quality standard (j)
M: Maximum
R: Average

There are several conditions for determining the value of an IP as follows:

1. Choose a parameter for which, if the parameter is low, the water quality is considered good.
2. Selecting a concentration of quality standard parameters that do not have a range;
3. Calculating the Ci/Li value of each test parameter with several conditions;
   a. If the parameter concentration is low compared to the quality standard, it can be said that pollution increases (e.g., DO). So the Ci/Li value used is (Equation 2):

$$\left(Ci/_{Li}\right)baru = \frac{C_{im} - C_{i(Hasil\ pengukuran)}}{C_{im} - L_i} \quad \ldots\ldots(2)$$

   b. If the quality standard value (Li) has a range, then Ci/Li is used:
      1. For the value of $Ci \leq Li_{(rata\text{-}rata)}$ (Equation 3):

$$\left(Ci/_{Li}\right)baru = \frac{C_i - L_{i(rata-rata)}}{L_{i(minimum)} - L_{i(rata-rata)}} \quad \ldots\ldots(3)$$

      2. For the value of $Ci > Li_{(rata\text{-}rata)}$ (Equation 4):

$$\left(Ci/_{Li}\right)baru = \frac{C_i - L_{i(rata-rata)}}{L_{i(maksimum)} - L_{i(rata-rata)}} \quad \ldots\ldots(4)$$

   c. If the value (Ci/Li) is adjacent to the value of 1, e.g., C1/L1 = 0.9 and C2/L2 = 1.1, or a distant difference, e.g., the parameters C1/L1 = 5 and C2/L2 = 10, then:
      1. Use (Ci/Li) if the result is less than 1,0
      2. Use (Ci/Li) *new* if the value of (Ci/Li) calculation result is more than 1,0, with formula (Equation 5):

$$(C_i/L_i)baru = 1{,}0 + P.log(Ci/Li) \quad \ldots\ldots(5)$$

P indicates a freely determined constant value adjusted to the results of environmental observations and/or the requirements for its designation (usually used as a value of 5). The quality value of IP water can be determined by the level of contamination, with the concentration value per parameter compared to the quality standard. Furthermore, according to KMLH No.115/2003, Appendix II, there are four IP index classes according to the evaluation of the IP value (Table 1).

Table 1. Evaluation of IP values

No.	IP Score	Description
1.	0-1,0	Good
2.	1,1-5,0	Lightly Polluted
3.	5,1-10	Moderately Polluted
4.	>10	Heavily Polluted

Source: Kepmen LH No.115 Tahun 2003

3. RESULT AND DISCUSSION

3.1 Result

The water quality used for marine tourism should meet the standard values physically, chemically, and biologically. Water quality is measured based on the quality standards for marine tourism purposes in the Decree of the Minister of Environment No. 22 of 2021. Table 2 shows the results of the analysis of chemical physics parameters in the waters east of Sabang City. Based on Table 2, the results of the study of the measurement of physical, chemical, and biological parameters showed that the characteristics of water pollution starting from 2020-2022 in the Water Pollution Index method were lightly polluted and moderately polluted. Thus, the most dominant pollution category is moderately polluted, with a score of 5.33 in 2020 at Mata Ie Resort. The lowest pollution was in 2021, reaching a value of 4.28 in 2021 at Mata Ie Resort.

Table 2. Water quality measurement results

Station	Years	IP score	Evaluation score
1. Sumur Tiga	2020	5.1	TS
	2021	4.9	TR
	2022	5.1	TS
2. Mata Ie Resort	2020	5.3	TS
	2021	4.2	TR
	2022	4.7	TR

Notes: TS (Moderately Polluted); TR (Lightly Polluted)

3.2 Discussion

It is very rare to find water in nature in its pure state. Even rainwater, which is initially pure, has reacted with gases in the air on its way down to the Earth and is subsequently contaminated as it flows above the Earth's surface and into the ground. Water quality expresses the level of suitability of water for its designation. Starting from drinking water needs, fisheries, recreation, and transportation (Suripin, 2002). The ocean covers 70% of the Earth's surface area, like a large pond that stores pollutants. Pollutants that enter the ocean are decomposable or non-decomposable. In addition, pollutants in the open sea come from seagoing vessels, emptying hulls, *ballast water*, and ship accidents (Machdar, 2010).

The aquatic area is a dynamic space that functions as a place for water to gather (Kartika et al., 2020). This area directly results from the continuous natural hydrological cycle, circling endlessly through the Earth's atmosphere. During precipitation, rainwater falls and flows carrying chemical elements that can benefit or harm humanity (Sunarsa, 2018). This water eventually returns to the sea, continuing the hydrological cycle while transporting dissolved chemicals that accumulate in the water (Soegianto, 2019). As a result, pollutants from both domestic and industrial waste are often carried through rivers or urban drainage systems into the sea or bay, causing environmental contamination and toxic effects on the biota of other living organisms (Awal et al., 2015; Ningsih, 2018).

The Water Pollution Index method compares the location of Mata Ie Resort with Sumur Tiga on the Northeast side of Sabang City from 2020 to 2022. The water quality pollutant parameters reviewed in this study were then compared with seawater quality standards by the Decree of the Ministry of Environment No. 22 of 2021. Suppose the value

of the results of the Pollution Index calculation is classified above number one (>1). In that case, the water quality is said to decline according to its designation and is classified as polluted water (Lubis, 2019).

The pollution index value is generated and calculated from the overall comparative value of the concentration of water quality parameters, with the concentration set by KMLH No. 22 of 2021, by the designation of marine tourism. Tables 3, 4, and 5 are three-year data at two stations. Figures 2 and 3 indicate a change in the concentration of each parameter, which exceeds the quality standard threshold but does not reach the standard quality limit. The concentration of seawater brightness in the Sumur Tiga and Mata Ie Resort 2020 (5; 3 m), 2021 (3; 3 m), and Sumur Tiga 2022 (4; 4m) did not reach the set quality standard limit (>6 meters), so this indicates a potential problem in seawater quality at these locations. Low brightness can indicate the presence of suspended particles, solutes, or other pollutants that reduce water transparency and affect the clarity of seawater in all three locations.

The turbidity of the waters refers to the ability of light to penetrate the water to a certain depth. This process is important for light-dependent marine organisms, such as phytoplankton. Light penetration is greater in deeper and clearer waters so that optimal photosynthesis can occur (Sari & Usman, 2012). The amount of sunlight that enters the water directly affects productivity. The conversion of sunlight into chemical energy occurs through photosynthesis in green plants, which is highly dependent on factors such as sunlight intensity, CO_2 concentration, dissolved oxygen, and water temperature. The imperfect penetration of light into the water is the main limiting factor for photosynthesis. Aquatic plants are very limited in number in a narrow area, so they depend highly on water clarity (Machdar, 2010).

Although the turbidity level did not reach the quality standards set for marine tourism, it is possible that the concentration of seawater turbidity in Sumur Tiga and Mata Ie Resort in 2020 (0.5; 2.49 NTU), 2021 (2.21; 4.28 NTU), and 2022 (4.5; 2.29 NTU) was above the quality standard threshold. The turbidity concentration from 2020 to 2022 has increased, which can provide an estimate that the next year will also increase, and may be able to exceed the threshold of the base (5 NTU). Turbidity occurs due to suspended materials of various sizes that interfere with the entry of light. Turbidity that exceeds the threshold of quality standards will decrease the health and productivity of estuarine waters. Rain factors, activities of the surrounding community, and physical oceanographic factors such as tides, currents, and turbulence cause high and low turbidity. Another cause is the presence of suspended materials and deposition when heading to the sea, so the turbidity value is very high (Mony, 2004).

Table 3. Comparison of measured concentration at two locations with quality standards (2020)

No	Test Parameters	Quality Standards (Li)	(Li) Average	Data Test Results					
				Mata Ie Resort	Ci/Li	Ci/Li new	Sumur Tiga	Ci/Li	Ci/Li new
1	Temp [^{0}C]	natural	natural	27.4		0	27.5		0
2	Brightness [m]	>6	>6	3		0	5		0
3	Turbidity [NTU]	5	5	2.49	0.498	0.498	0.5	0.1	0.1
4	TSS [mg/l]	20	20	10	0.5	0.5	12	0.6	0.6
5	Salinity [$^0/_{00}$]	natural	natural	19.7		0	16.9		0
6	Biologycal Oxygen Demand (BOD)	10	10	1.7	0.17	0.17	1.9	0.19	0.19
7	Dissolved Oxygen (DO) [mg/L]	>5	>5	4.59		0	6.23		0
8	Acidity (pH)	7–8.5	7.75	7.9	0.2	0.2	7.53	0.53	0.53
9	Ammonia Total (NH_3-N) [mg/L]	0.02	0.02	0.03	1.5	1.88	0.0001	0.005	0.005
10	Nitrate (NO_3-N) [mg/L]	0.06	0.06	0.8	13	7	1	17	7.109
11	Phosphate (PO_4-P) [mg/L]	0.015	0.015	0.295	19.67	7.468	0.17	11.33	6.272
12	Sulphide (H_2S) [mg/L]	0.002	0.002	0.0001	0.05	0.05	0.0001	0.05	0.05
13	Colour [Pt-Co]	30	30	4	0.133	0.13	12	0.4	0.4
14	Odor	*TB	*TB	*TB	*TB	0	*TB	*TB	0
15	Oil Coating [mg/L]	nul	nul	nul		0	nul		0
16	Mercury (Hg) [mg/L]	0.02	0.02	0.0005	0.025	0.025	0,0005	0.025	0.025
17	Cromium Hexavalen (Cr6+) [mg/L]	0.02	0.02	0.01	0.5	0.5	0.01	0.5	0.5
18	Cadmium (Cd) [mg/L]	0	0.002	0.0004	0.2	0.2	0.0004	0.2	0.2
19	Zinc (Zn) [mg/L]	0.1	0.095	0.0001	0.001	0.001	0.0001	0.001	0.001
20	Surfactan (MBAS) [mg/L]	0.001	0.001	0.01	10	6	0.012	12	6.396
21	Fatty Oils [mg/L]	1	1	0.1	0.1	0.1	0.1	0.1	0.1
22	Lead (Pb) [mg/L]	0.01	0.005	0.0001	0.02	0.02	0.0001	0.02	0.02
23	Tembaga (Cu) [mg/L]	0.05	0.05	0.0008	0.016	0.016	0.0008	0.016	0.016
24	Nickel (N) [mg/L]	0.08	0.075	0.001	0.013	0.013	0.001	0.013	0.013
	$(C_i/L_i)_{new}$ Maximum					7.468			7.109
	$(C_i/L_i)_{average}$					1.016			0.938
	** IP score					5.329			5.070

Notes: Natural is the normal condition of an environment, which varies at any time (day, night, and season), *TB: No odor, **Pollution Index Value, equation (3.1)

Table 4. Comparison of the measured concentrations at two locations with quality standards (2021)

No	Tested Parameter	Quality Standards (Li)	(Li) Average	Data Test Results					
				Mata Ie Resort	Ci/Li	Ci/Li new	Sumur Tiga	Ci/Li	Ci/Li new
1	Temp [^{0}C]	natural	natural	28.5		0	28.6		0
2	Brightness [m]	>6	>6	3		0	3		0
3	Turbidity [NTU]	5	5	4.28	0.856	0.662	2.21	0.442	0.442
4	TSS [mg/l]	20	20	15.8	0.79	0.79	12.2	0.61	0.61
5	Salinity [$^0/_{00}$]	natural	natural	3.449			23.4		
6	Biologycal Oxygen Demand (BOD)	10	10	2.58	0.258	0.258	0.99	0.099	0.099
7	Dissolved Oxygen (DO) [mg/L]	>5	>5	7.51		0	7.92		0
8	Acidity (pH)	7–8.5	7.75	7.98	0.307	0.307	7.92	0.227	0.227
9	Ammonia Total (NH_3-N) [mg/L]	0.02	0.02	0.02	1	1	0.002	0.1	0.1
10	Nitrate (NO_3-N) [mg/L]	0.06	0.06	0.6	10	6	0.9	15	6.88
11	Phosphate (PO_4-P) [mg/L]	0.015	0.015	0.11	7.333	5.327	0.12	8	5.515
12	Sulphide (H_2S) [mg/L]	0.002	0.002	0.0001	0.05	0.05	0.0001	0.05	0.05
13	Colour [Pt-Co]	30	30	4	0.133	0.133	6	0.2	0.2
14	Odor	*TB	*TB	*TB	*TB	0	*TB	*TB	0
15	Oil coating [mg/L]	nul	nul	nul		0	nul		0
16	Waste [Visual]	nul	nul	nul		0	nul		0
17	COD [mg/L]	-	-	17.58		0	14.37		0
18	Nitrit (NO_2-N) [mg/L]	-	-	0.04		0	0.006		0
19	Cyanide [mg/L]	-	-	0.001		0	0.001		0
20	Chloride (Cl) [mg/L]	-	-	0.01		0	0.02		0
21	Mercury (Hg) [mg/L]	0.02	0.02	0.001	0.05	0.05	0.001	0.05	0.05
22	Fecal Coliform [100 mg/L]	200	200	17	0.085	0.085	12	0.06	0.06
	$(C_i/L_i)_{new}$ Maximum					6			6.880
	$(C_i/L_i)_{average}$					0.698			0.677
	**IP score					4.271			4.888

Notes: Natural is the normal condition of an environment, which varies at any time (day, night, and season), *TB: No odor, **IP score, equation (3.1)

Table 5. Comparison of measured concentrations at two locations with quality standards (2022)

No	Tested Parameters	Quality Standards (Li)	(Li) Average	Data Test Results					
				Mata Ie Resort	Ci/Li	Ci/Li new	Sumur Tiga	Ci/Li	Ci/Li new
1	Temp [^{o}C]	Alami	alami	29.7		0	30.2		
2	Brightness [m]	>6	>6	4		0	4		
3	Turbidity [NTU]	5	5	2.29	0.458	0.458	4.21	0.842	0.842
4	TSS [mg/L]	20	20	7.8	0.39	0.39	8.3	0.415	0.415
5	Salinity [$^0/_{00}$]	natural	natural	44.48		0	44.46		
6	Biologycal Oxygen Demand (BOD)	10	10	1.1	0.11	0.11	1.1	0.11	0.11
7	Dissolved Oxygen (DO) [mg/L]	>5	>5	7.37		0	7.19		
8	Acidity (pH)	7–8.5	7.75	8.62	1.16	1.322	8.61	1.147	1.297
9	Ammonia Total (NH_3-N) [mg/L]	0.02	0.02	0.006	0.3	0.3	0.026	1.3	1.57
10	Nitrate (NO_3-N) [mg/L]	0.06	0.06	0.8	13.33	6.625	1	16.67	7.109
11	Phosphate (PO_4-P) [mg/L]	0.015	0.015	0.1	6.667	5.12	0.12	8	5.515
12	Sulphide (H_2S) [mg/L]	0.002	0.002	0.0001	0.05	0.05	0.0001	0.05	0.05
13	Colour [Pt-Co]	30	30	4	0.133	0.13	4	0.133	0.13
14	Odor	*TB	*TB	*TB	*TB	0	*TB	*TB	0
15	Oil coating [mg/L]	nul	nul	nul		0	Nul		0
16	Waste [Visual]	nul	nul	nul		0	nul		0
17	COD [mg/L]	-	-	13.59		0	15.29		0
18	Nitrite [mg/L]	-	-	0.011		0	0.011		0
19	Cyanide [mg/L]	-	-	0.001		0	0.001		0
20	Klorin Bebas (Cl_2) [mg/L]	-	-	0.02		0	0.1		0
21	Total Phosphate [mg/L]	-	-	0.1		0	0.12		0
22	Fecal Caliform [100 mg/L]	200	200	25	0.125	0.125	24	0.12	0.12
	$(C_i/L_i)_{new}$ Maximum					6.624			6.624
	$(C_i/L_i)_{average}$					0.664			0.953
	**IP score					4.707			5.074

Natural is the normal condition of an environment, which varies at any time (day, night, and season)

TSS also contributes to turbidity by limiting light penetration for photosynthesis and water visibility. Observation data in the three Tables (Tables 3, 4, and 5) show that the TSS value meets the standard quality standards for marine tourism designation. Generally, the higher the TSS in the water, the lower the brightness of the water. Although the TSS level meets the quality standards, other factors can affect the brightness and turbidity of the water, namely surfactants. As stated by Connel & Miller (1998), Surfactants can play a role in influencing the concentration of TSS in water by dispersing it into smaller particles. With a reduction in TSS concentration, the brightness and turbidity of the water can be improved. The concentrations of TSS in seawater in Sumur Tiga and Mata Ie Resort 2020 (12; 10 mg/L), Sumur Tiga 2021 (12.2; 15.8 mg/L), and 2022 (8.3; 7.8 mg/L) are below the standard threshold for marine tourism quality (20 mg/L). This result shows that the TSS content in this location is still at a good content level, and even in 2022, the TSS level has decreased significantly, which can provide evidence that turbidity will remain below the standard threshold for marine tourism quality.

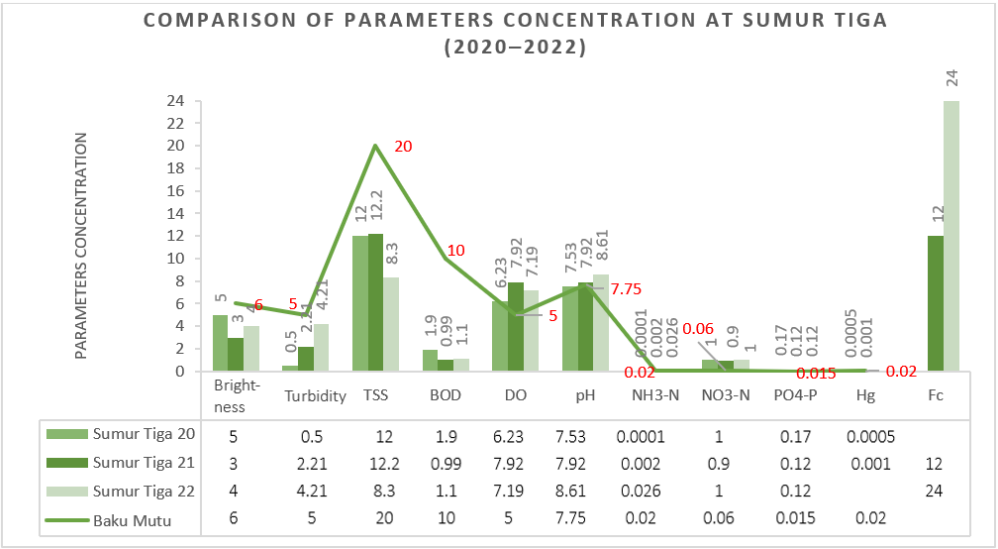

Figure 2. Comparison graph of concentration levels at Sumur Tiga (2020–2022)

Surfactants are substances that can help reduce the surface tension of the water, so that they can affect the size of suspended solid particles (TSS) in water. If the water contains high surfactants, surfactants can help break down the initially significant TSS into smaller, scattered particles in the water. If surfactants are present and help disperse TSS, then the amount of suspended solid particles is reduced, and as a result, the brightness of the water can increase. In the Surfactant comparison, the surfactant concentration level was higher in Sumur Tiga (0.012 mg/l) than in Mata Ie Resort (0.01 mg/l), which exceeded the marine tourism quality standard (0.001 mg/l). As a result, the loss of living marine organisms such as plankton, fish, coral reefs, and other animals due to surfactants can impact marine tourism. Marine tourism involves various activities such as diving, snorkelling, swimming, surfing, and sailing. This activity depends on good water quality. Poor seawater quality can reduce tourists' satisfaction value.

Dissolved oxygen (DO) and biological oxygen demand (BOD) are interrelated with oxygen in water. DO measures the amount of dissolved oxygen present in water, while BOD indicates the amount of oxygen required by microorganisms in metabolizing dissolved organic matter. The concentration of BOD (biological oxygen demand) in seawater in Sumur Tiga and Mata Ie Resort in 2020 (1.9; 1.7 mg/L), 2021 (7.92; 2.58 mg/L), and 2022 (1.1; 1.1 mg/L) experienced a spike in concentration in 2021 even though it was still limited to the quality standards set for marine tourism (10). In addition, the concentration of DO plays an important role in determining the adequacy level of dissolved oxygen in seawater. A high DO value usually indicates good water quality, while a low DO value can indicate a problem in water quality. Based on the standardized DO content value of >5 with a concentration of 6.23, 4.59 in 2020, 7.92, 7.51 in 2021, and 7.19, 7.37 in 2022. However, there are differences in dissolved oxygen concentrations between those years; the relatively high DO concentration indicates adequate dissolved oxygen in seawater. TSS and BOD in marine waters also tend to be lower due to the lack of freshwater flows that carry organic waste and solid particles into the sea. Higher temperatures during the dry season in marine waters can lead to decreased DO levels. High temperatures and a lack of freshwater flows carrying oxygen can reduce the availability of dissolved oxygen in seawater (Fardiaz, 1992).

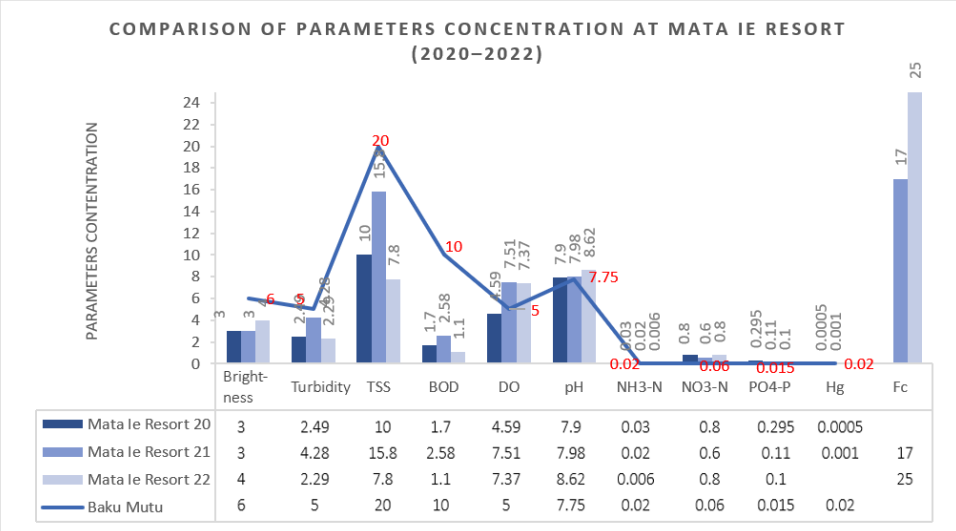

Figure 3. Comparison graph of concentration levels at Mata Ie Resort (2020–2022)

In the context of seawater quality, a pH that exceeds the quality standard limit can indicate a significant change in the acidity level of seawater. Excessive acidity can hurt marine organisms and marine ecosystems as a whole. In 2020 (7.53; 7.9) and 2021 (7.92; 7.98), the pH content in Sumur Tiga and Mata Ie Resort was still within the quality standard threshold and was still fairly neutral. However, in 2022, there was a spike in acid (8.61; 8.62). The acidity level of the waters is a critical water quality parameter in the ecosystem. A slight change in pH from the natural pH will provide a CO_2 imbalance that can harm marine life. Moreover, high and low pH can be affected by O_2 or CO_2 content (Rukminasari et al, 2014). Water not neutral to the normal pH range is unsuitable for aquatic organisms (Aryulina et al., 2004).

The concentration values of Ammonia have increased in Sumur Tiga and Mata Ie Resort from 2020 (0.0001; 0.03 mg/l), 2021 (0.002; 0.02 mg/l), and 2022 (0.026; 0.006 mg/l). Although Ammonia increased in 2021 and 2022, the concentration in Sumur Tiga remained within the marine tourism's quality standard threshold (0.02 mg/l). The source of Ammonia in waters is the fraction of organic and inorganic nitrogen that occurs in the soil and water. The high presence of Ammonia will interfere with the existence of organisms around these waters. With increased dissolved oxygen, Ammonia will undergo nitrification in the waters, become nitrite, and subsequently nitrate. So that Ammonia does not affect the condition of the waters too much (Sumantri, 2011).

This case contrasts with nitrate and phosphate, which exceed marine tourism's quality standards (0.06 mg/l and 0.015 mg/l). Nitrates are the main form of nitrogen in the waters and are the primary nutrient for the growth of plants and algae. However, a body of water is said to be polluted by nitrate if the nitrate level is more than 0.1mg/liter. Moreover, if the nitrate level reaches more than 5mg/liter, pollution from human activities and animal feces occurs (Kamsuri et al., 2013). The entry of nitrates into the river body is due to humans throwing dirt into the river water, which contains much Ammonia. Other things that can cause high nitrate concentrations are the decay of plant and animal waste, industrial disposal, and animal manure. The presence of nitrates in river bodies is due to human activities, such as dumping sewage into water containing high amounts of Ammonia. Other factors contributing to increased nitrate concentrations include plant and animal decay, industrial waste, and animal manure. Nitrate levels exceeding 0.2 mg/l can cause eutrophication, triggering the rapid growth of phytoplankton *(blooming)* (Effendi, 2003). To manage sources of pollution, implementing sustainable agricultural practices and utilizing efficient waste treatment technologies can help lower nitrate and phosphate levels, thereby aiding in the recovery of marine ecosystems.

As for fecal coliform, it is a bacterium that indicates water quality cleanliness. This bacterium belongs to the *Escherichia coli* (*E. coli*) group, which can be found in human and animal feces. Water can contain many different living organisms, macroscopic, microscopic, and bacterial. Bacteria are small organisms whose species are challenging to identify even with a microscope. *Escherichia coli* is a non-pathogenic bacterium that inhabits the intestines of warm-blooded animals and is usually found in water in animal or human feces. The presence or absence of this bacterium is used to assess water quality through the *E. coli* test (Suripin, 2008). Fecal Coliform in 2020 did not record the presence of fecal coliform in both locations. Meanwhile, in 2021 (12; 17) and 2022 (24; 25), the number was far below the quality standard limit (200), which can be categorized as safe in terms of fecal coliform.

Overall, the results of parameter and concentration measurements show potential problems in seawater quality in Sumur Tiga and Mata Ie Resort in 2020-2022. Several parameters indicate the presence of pollution that affects transparency, turbidity, suspended solids content, dissolved oxygen, nutrients, and the presence of living organisms in marine waters. Dahuri et al. (2001) emphasized that water with values exceeding the set quality standard threshold threatens marine life and the environment, endangers human health, and can cause negative socio-economic impacts. Parameters that exceed the quality standards cause water conditions to be polluted and exceed the quality standards established by KMLH No. 21.

4. CONCLUSION

Based on the results of a study on the quality of waters in the East of Sabang City from 2020 to 2022 in two different locations intended for Marine Tourism, it was found that the characteristics of water pollution in 2020 in Sumur Tiga were moderately polluted (5.1) and in Mata Ie Resort moderately polluted (5.3); in 2021 in Sumur Tiga was lightly polluted (4.9) and in Mata Ie Resort lightly polluted (4.3); and 2022 in moderately polluted Sumur Tiga (5.1) and in Mata Ie Resort lightly polluted (4.7). The highest pollution level was in Mata Ie Resort Anoi Hitam in 2020, with the category of medium pollution, and the lowest pollution level was in Mata Ie Resort Anoi Hitam in 2021, with the level of light pollution.

ACKNOWLEDGEMENT

The author expresses his gratitude to the Head of DLHK Sabang City, who has allowed the author to obtain data as research material for the Eastern region of Sabang City. Also, thank you to the Head of the Sabang City DKP for the assistance and discussion during the research. Moreover, the author expresses his gratitude to Muhammad Hafiz Farhan S.Pi for the assistance with funds during the implementation of this research.

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